

What is claimed is:

Subal 1. A multilayer ceramic coating for providing thermal barrier protection to a substrate comprising an inner ceramic layer coating the substrate, the inner ceramic layer having a plurality of macrocracks distributed throughout the inner ceramic layer, and an outer ceramic layer coating the inner ceramic layer, the outer ceramic layer being substantially free of vertical macrocracks.

2. The multilayer coating of claim 1 wherein the cracks of the inner ceramic layer are vertical macrocracks.

Subal 3. The multilayer coating of claim 1 wherein the cracks of the inner ceramic layer are vertical and horizontal macrocracks.

4. The multilayer coating of claim 1 wherein the inner ceramic layer includes at least a first cracked layer and a second cracked layer.

5. The multilayer coating of claim 1 wherein the inner ceramic layer has a porosity that increases from an inner surface of the inner ceramic layer to an outer surface of the inner ceramic layer.

6. The multilayer coating of claim 1 wherein the outer ceramic layer has a porosity that increases from an inner surface of the outer ceramic layer to an outer surface of the outer ceramic layer.

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7. The multilayer coating of claim 1 wherein the cracks are vertical macrocracks that extend at least the lesser of about 0.1 mm in length or one half the thickness of the inner ceramic layer.

8. The multilayer coating of claim 1 wherein the cracks are vertical segmentation macrocracks that extend at least one half the thickness of the inner ceramic layer and there are from about 7.5 to 75 vertical macrocracks per linear centimeter.

sub 9. The multilayer coating of claim 3 wherein the total horizontal macrocracks extend from about 15 to 100% as measured across a plane normal to an interface of the substrate with the multilayer coating.

10. The multilayer coating of claim 9 wherein the total horizontal macrocracks extend from about 20 to 60% as measured across a plane normal to an interface of the substrate with the multilayer coating.

11. A multilayer zirconia-based coating for providing thermal barrier protection to a substrate comprising an inner zirconia-based layer coating the substrate, the inner zirconia-based layer having a plurality of vertical macrocracks distributed throughout the inner zirconia-based layer, and an outer zirconia-based layer coating the inner zirconia-based layer, the outer zirconia-based layer being substantially free of vertical macrocracks.

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12. The multilayer zirconia-based coating of claim 11 wherein the inner zirconia-based layer includes horizontal macrocracks.

13. The multilayer zirconia-based coating of claim 11 wherein the inner zirconia-based includes at least a first cracked layer and a second cracked layer.

14. The multilayer coating of claim 11 wherein the inner zirconia-based layer has a porosity that increases from an inner surface of the inner zirconia-based layer to an outer surface of the inner zirconia-based layer.

15. The multilayer coating of claim 11 wherein the outer zirconia-based layer has a porosity that increases from an inner surface of the outer zirconia-based layer to an outer surface of the outer zirconia-based layer.

16. The multilayer zirconia-based coating of claim 11 wherein there are from about 7.5 to 75 of the vertical segmentation macrocracks per linear centimeter.

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17. The multilayer zirconia-based coating of claim 12 wherein the horizontal macrocracks are from about 0.1 to 2.5 mm in length and the total horizontal macrocracks extend from about 15 to 100% as measured across a plane normal to an interface of the substrate with the multilayer zirconia-based coating.

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Sub a 18. The multilayer zirconia-based coating of claim 17 wherein the total horizontal macrocracks extend from about 20 to 60% as measured across a plane normal to an interface of the substrate with the multilayer zirconia-based coating.

19. The multilayer zirconia-based coating of claim 11 wherein the outer zirconia-based layer has a density of about 45 to 90% of theoretical.

20. The multilayer zirconia-based coating of claim 11 wherein the outer zirconia-based layer has a density of about 50 to 86% of theoretical.

21. The multilayer zirconia-based coating of claim 11 wherein the outer zirconia-based layer has a density of about 50 to 70% of theoretical.

22. The multilayer zirconia-based coating of claim 11 wherein the inner and outer zirconia-based layers have a total thickness of about 0.2 mm to about 10 mm.

23. The multilayer zirconia-based coating of claim 11 wherein the inner and outer zirconia-based layers have a total thickness of at least about 2 mm.

24. The multilayer zirconia-based coating of claim 11 wherein the multilayer zirconia-based coating contains a stabilizing element for partially or full stabilizing the at least one crystallographic phase selected from the group of tetragonal and cubic.

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Suba! 25. The multilayer zirconia-based coating of claim 11 including a bondcoat between the substrate and the inner zirconia-based layer.

26. The multilayer zirconia-based coating of claim 25 wherein the bondcoat contains at least one inner sublayer and an outer sublayer, and the outer sublayer has a surface roughness of at least about 3.8  $\mu\text{m}$  as measured before the application of the inner zirconia-based layer to the outer sublayer.

27. The multilayer zirconia-based coating of claim 25 wherein the bondcoat is sealed with a heat treatment.

28. A substrate having a multilayer ceramic coating for providing thermal barrier protection to at least a portion of the substrate, the multilayer ceramic coating comprising an inner ceramic layer coating the substrate, the inner ceramic layer having a plurality of cracks distributed throughout the inner ceramic layer, and an outer ceramic layer coating the inner ceramic layer, the outer ceramic layer being substantially free of vertical macrocracks.

29. The substrate of claim 28 wherein the substrate is a component of a gas turbine engine.

30. The substrate of claim 28 wherein the substrate is an air seal for a gas turbine engine.

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31. The substrate of claim 30 wherein the multilayer coating is an abradable coating.

32. The substrate of claim 31 wherein the air seal opposes a blade tip or knife edge.

33. A substrate having a multilayer zirconia-based coating for providing thermal barrier protection to at least a portion of the substrate, the multilayer zirconia-based coating for providing thermal barrier protection to a substrate comprising an inner stabilized zirconia layer coating the substrate, the inner stabilized zirconia layer having a plurality of vertical macrocracks distributed throughout the inner stabilized zirconia layer, and an outer stabilized zirconia layer coating the inner stabilized zirconia layer, the outer stabilized zirconia layer being substantially free of vertical macrocracks.

34. The substrate of claim 33 wherein the substrate is a component of a gas turbine engine.

35. The substrate of claim 33 wherein the substrate is an air seal for a gas turbine engine.

36. The substrate of claim 35 wherein the multilayer coating is an abradable coating.

37. The substrate of claim 36 wherein the air seal opposes a blade tip or knife edge.

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sub a 7 38. The substrate of claim 33 wherein the inner stabilized zirconia layer contains a first layer having a first conductivity and a first thickness and a second layer having a second thermal conductivity and a second thickness for combining two different thermal conductivities and for forming a desired total thermal conductivity and a desired total thickness.

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